

# ***PMRC IAB Meeting***

**October 15, 2003**

## ***Turning Hardened Steel Using Rotary Tool***

- **Graduate Research Assistants:**

**Sathyan Subbiah, Ph.D candidate**

**Vincent Dessoly, M.S. student**

- **Advisor:**

**Dr. Shreyes N. Melkote, Associate Professor**

# Overview

1. Introduction
2. Self-propelled rotary tools (SPRT)
3. Surface integrity study
4. Temperature prediction model
5. Ongoing/Future work
6. Conclusions

# Introduction

Introduction	SPRT	Surface integrity	Temperature model	Next studies	Conclusions
Situation	Challenges				

- Turning process being considered by industry to finish machine hardened steel parts
- Should be competent with well-established grinding process
- Challenges in hard turning process:
  - Surface integrity (white layer)
  - Economical tool life
- Studies on surface integrity and tool wear important to make hard turning viable

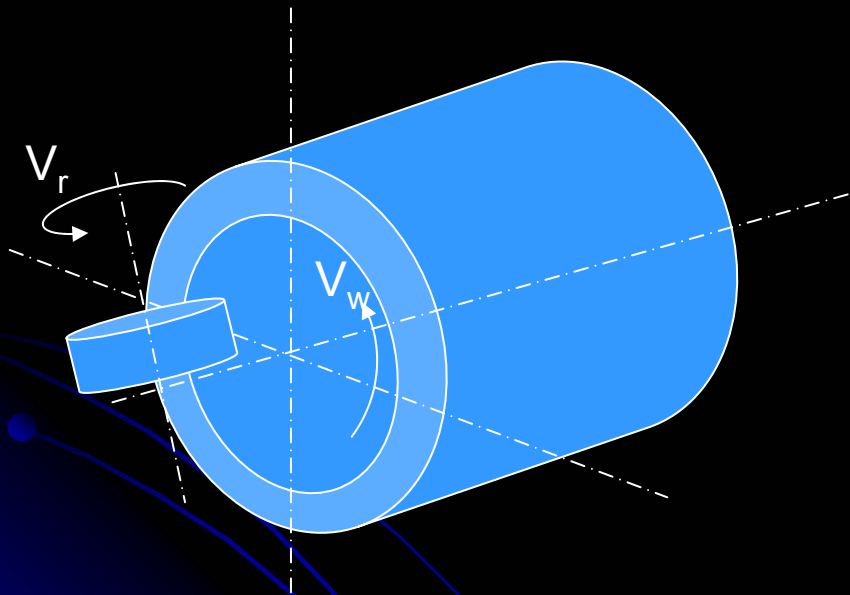
# Hard Turning Challenges

Introduction	SPRT	Surface integrity	Temperature model	Next studies	Conclusions
Situation	Challenges				

- White layer:
  - Featureless layer after etching
  - Different properties from bulk
  - Not desirable
  - Formed easily under aggressive conditions
  - Thermal phenomenon suspected
  - Need to reduce temperature
- Tool wear:
  - PCBN tool wear can be high
  - Need to improve tool life

# Rotary Tools

Introduction	SPRT	Surface integrity	Temperature model	Next studies	Conclusions
Process	Features				

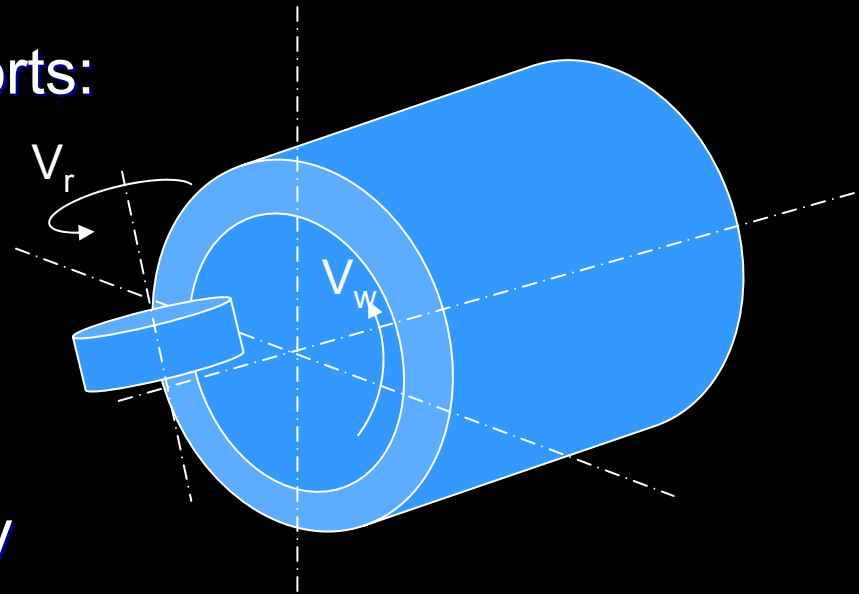


Self-propelled rotary tool process.

# Features of Rotary Tool

Introduction	SPRT	Surface integrity	Temperature model	Next studies	Conclusions
Process	Features				

- With rotary tools, literature reports:
  - Lower cutting temperature
  - Lower forces
  - Lower tool wear
- Effect of this on hard turning?
  - Task 1: Surface integrity study
  - Task 2: Temperature and wear studies

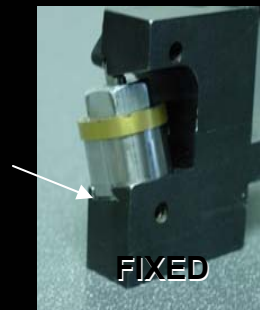


# Task 1: Surface Integrity

Introduction	SPRT	Surface integrity	Temperature model	Next studies	Conclusions
Situation	White layer	Conclusions			

- Perform experiments to compare surface integrity under fixed and rotary tool conditions

Fixed tool  
cartridge made  
similar to rotary  
unit



**$V = 60 \text{ m/min},$   
 $80 \text{ m/min},$   
 $100 \text{ m/min}$   
 **$f = 0.2 \text{ mm/rev}$   
 **$\text{DOC } 0.1\text{mm}$******



Rotary  
cartridge

- Workpiece: 52100 steel; ~58 HRC
- Tool: micrograin carbide with proprietary nano-coating (Rotary Technologies Inc.)
- Hardinge Precision Lathe T42SP
- Thermal analysis to confirm observed trends

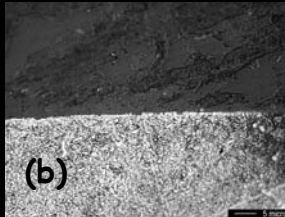
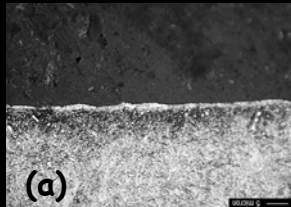
# Task 1: Surface Integrity

Introduction	SPRT	Surface integrity	Temperature model	Next studies	Conclusions
Situation	White layer	Conclusions			

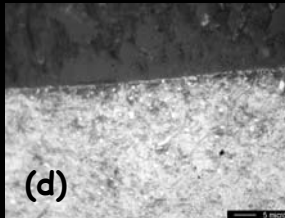
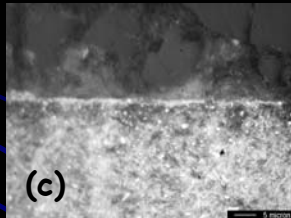
Fixed

Rotary

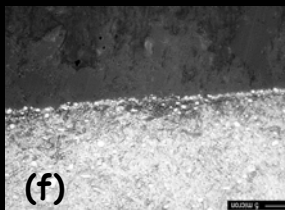
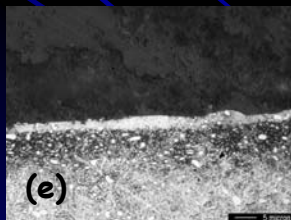
V60



V80



V100



- Well established theories in orthogonal, oblique and rotary tool cutting used
- Q: amount of heat transferred to workpiece
- $R_1$ : heat partition coefficient

	FIXED		ROTARY	
	$R_1$	Q (J)	$R_1$	Q (J)
V100	0.36	188.4	0.53	6.7
V 80	0.34	141.1	0.50	11.8
V60	0.31	131.9	0.46	18.5



# Surface Integrity Summary

Introduction	SPRT	Surface integrity	Temperature model	Next studies	Conclusions
Situation	White layer	Conclusions			

- White layer less likely to form under rotary tool cutting
- Lower tool wear seen in rotary cutting
- Worn tools are known to produce white layer
- Analytical calculations show less heat is going into workpiece
- A combination of thermal and lower wear could be the cause of the thin/absent white layer

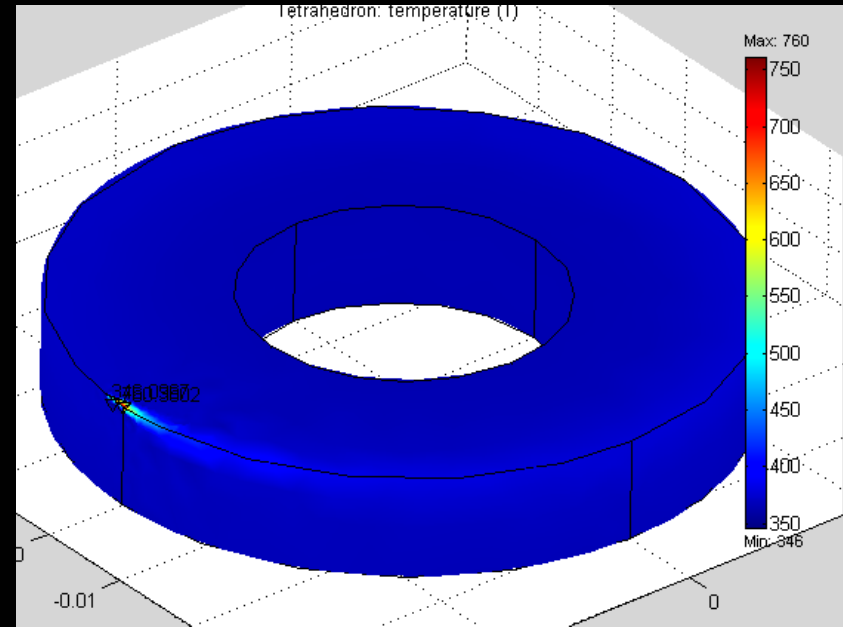
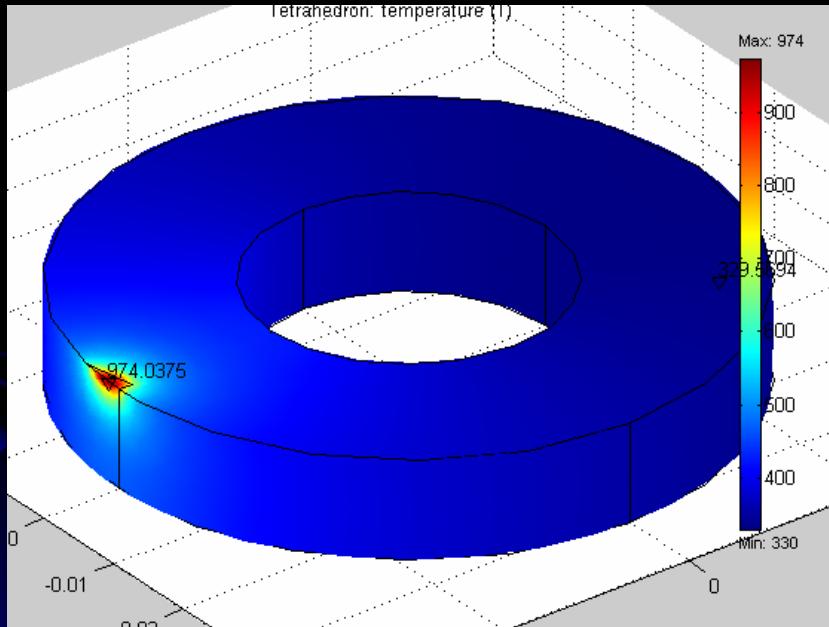
# Task 2: Temperature Modeling

Introduction	SPRT	Surface integrity	Temperature model	Next studies	Conclusions
General	Results	Discussions			

- The analysis is based on data given by Shaw in a previous study when turning a steel tube with a *driven* orthogonal rotary tool
- The approach uses the finite element method (FEM). The required equation is derived from heat conduction theory
- The method involves modeling the rotating tool with a transport term added to the heat equation
- Numerical computation is performed with FEMLAB

# Temperature Distribution

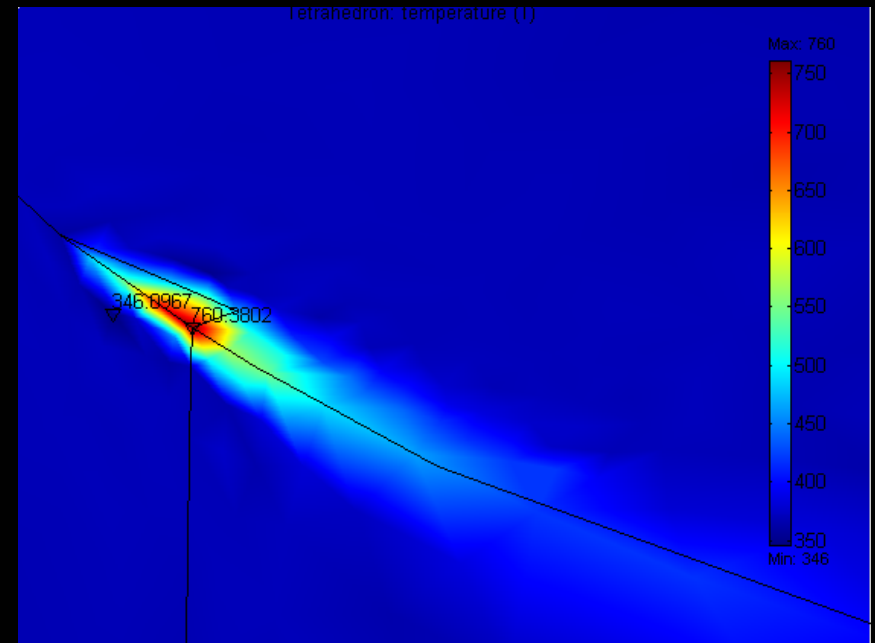
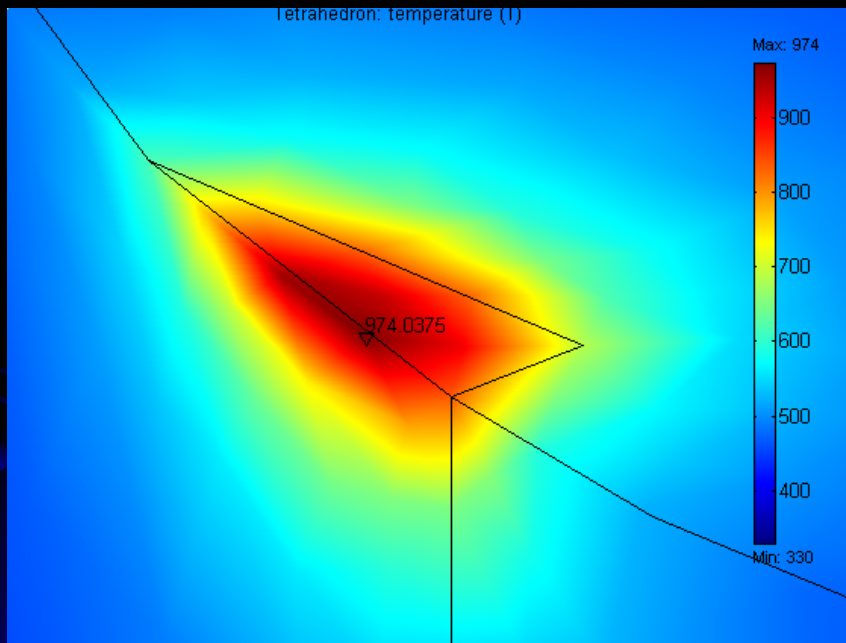
Introduction	SPRT	Surface integrity	Temperature model	Next studies	Conclusions
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Temperature distributions in fixed and rotary tools

# Temperature Distribution

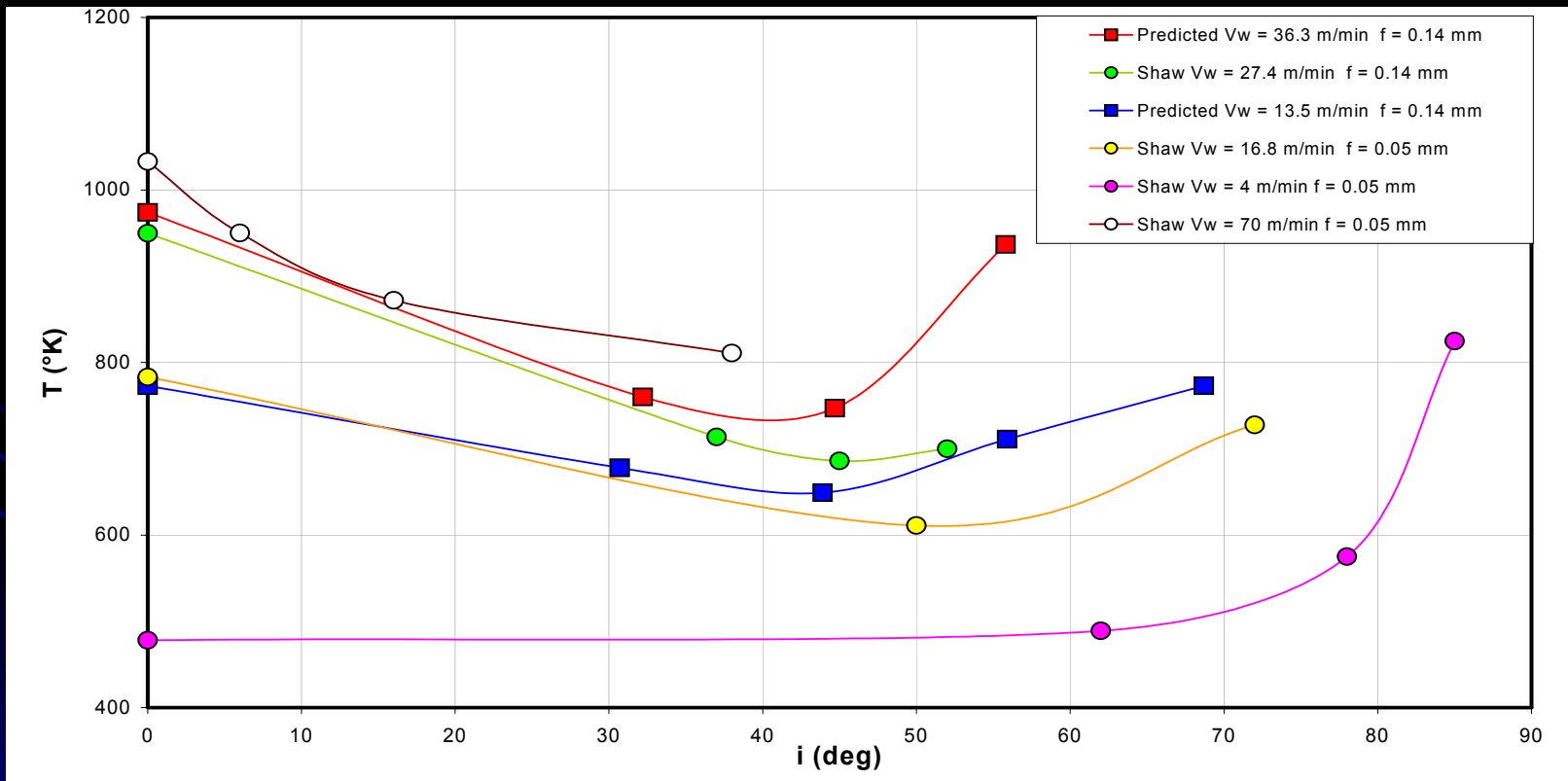
Introduction	SPRT	Surface integrity	Temperature model	Next studies	Conclusions
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Temperature distributions in fixed and rotary tools

# Cutting Temperature

Introduction	SPRT	Surface integrity	Temperature model	Next studies	Conclusions
General	Results	Discussions			



# Discussion

Introduction	SPRT	Surface integrity	Temperature model	Next studies	Conclusions
General	Results	Discussions			

- Model needs tool-chip interface geometry parameters
- This model can also be used for a self-propelled rotary tool process
- Results given by the model show good agreement with measurements of Shaw
- Rotary tool temperatures are about 200°C lower than for an equivalent fixed tool
- Results thus far are promising for planned study of rotary tool wear

# Ongoing/Future Work

Introduction	SPRT	Surface integrity	Temperature model	Next studies	Conclusions
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- Further validate the temperature prediction model
- Compare the temperature distributions for both fixed and rotary tools
- Correlate temperature and wear of fixed and rotary tools
- Tool life

# Conclusions

Introduction	SPRT	Surface integrity	Temperature model	Next studies	Conclusions
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- Improved surface integrity with rotary tool
- The lower temperature prediction is promising in terms of rotary tool wear
- These two aspects should make rotary tool hard turning viable

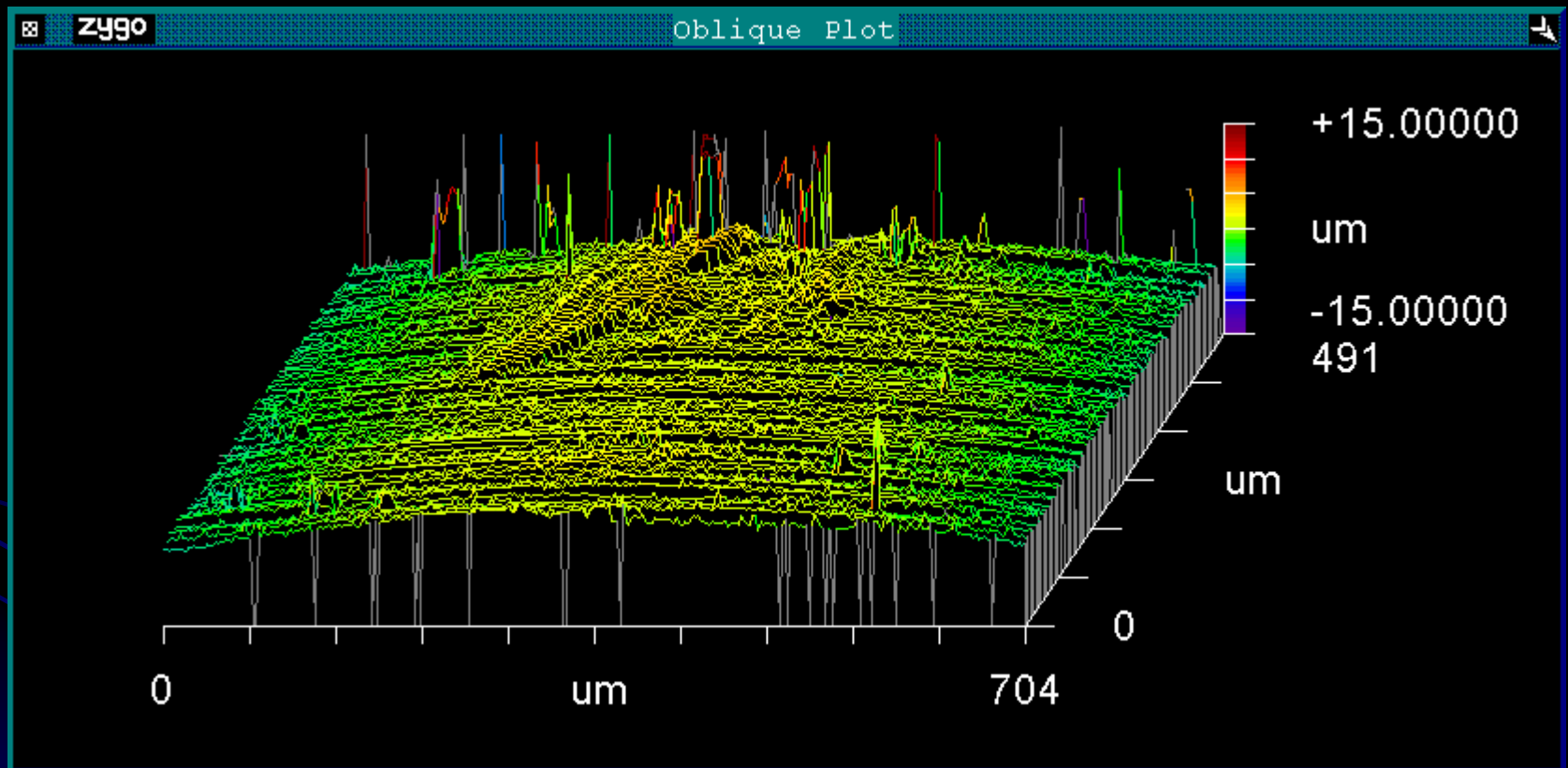


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Thank you for your attention.  
Any questions or comments?

# Flank wear



# Flank wear

